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FIREFIGHTER VEHICLE TRAINING SIMULATOR CONCEPTUAL DESIGN

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NOVEMBER 1981

FINAL REPORT
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suppression simulator. One of the major outputs of the study was a video tape demonstrating the theatrical techniques and realistic capabilities of the designed simulator system.

PREFACE

This report was prepared by the Fire Research Corporation, 26 Southern Boulevard, Nesconset, New York 11767, for the Air Force Engineering and Services Center, Engineering and Services Laboratory at Tyndall AFB, Panama City, Florida 32401. This report was prepared under Job Order Number 2505-2002, Fire Fighter Training Simulator.

This report covers the period beginning September 80 and ending September 81.

This report has been reviewed by the Public Affairs (PA) officer and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

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SECTION I

INTRODUCTION

1. OBJECTIVE

The objective of this project was to develop a conceptual design for a fire fighter vehicle training simulator which can be used to train Air Force fire fighters in fire suppression, vehicle operations, turret operations, decision making, tactics, and communications.

2. BACKGROUND

Currently, crash rescue fire fighter training at base fire department level consists of on-the-job training for newly assigned fire fighters and recurring proficiency training for qualified fire protection specialists. The training of fire fighters requires considerable time and resources. Valuable resources are consumed in creating and extinguishing live fires. While these training situations expose a fire fighter to heat, smoke and noise of a fire, they are relatively short, the environment is degraded, and the fire situation is not reproducible due to wind, weather, etc.

Increased environmental restrictions on the open burning of hydrocarbon fuel, and increased maintenance and fuel costs for fire fighting vehicles have resulted in severe restraints on fire fighter training. Indications are that environmental restrictions will continue to increase. Use of fire fighting vehicles for training will become increasingly cost prohibitive because of increased maintenance and fuel costs. Fuel shortages and environmental constraints have made the continuance of these types of training increasingly unacceptable. The effect of these trends is that the proficiency level of the Air Force fire fighter is decreasing. This is due to an 80 percent turnover in first term fire fighters and reduced actual fire training because of fuel shortages.

An objective rating scale for fire fighter training is difficult to establish because of continuously changing circumstances. Due to the consistently large turnover of personnel, maintenance costs of the vehicle fleet, and fuel consumption, it was determined that a more economical method of training fire fighters is needed. A simulator will augment actual vehicle use and live fires for training fire fighters at base level.

3. APPROACH

A concept study was conducted on the feasibility of developing a fire fighter vehicle training simulator. The study included: an analysis of visible smoke and flame, a state-of-the-art assessment of commercial simulators and visual techniques, and the conceptual design of a simulator to meet USAF requirements.

SECTION II

ANALYSIS OF DARK SMOKE AND REAL FLAME

A study of flame and smoke produced at crashed aircraft and fuel spill fires is particularly important to crash truck operations and fire fighters. Thus, a closer look at the combustion process was accomplished. Common fires of this type involve fuel leaks and spills. As these fuels vaporize, mix with the air, and ignite, carbon oxidizes to carbon monoxide and carbon dioxide. Each of these products of combusion is an odorless, colorless gas.

Carbon dioxide forms when a plentiful supply of air is available at the combustion site or when fuel is burned in pure oxygen. The formation of carbon monoxide occurs when the mixture is especially rich in vapor of the combustible fuel or when the supply of air (oxygen) is limited. When burned in air, most fuels yield a mixture of both carbon monoxide and carbon dioxide. This mixture is normally accompanied by the formation of voluminous amounts of smoke. For example, when methane burns in a plentiful supply of air, the products of combustion are carbon dioxide and water. When the supply of oxygen is limited, carbon monoxide and water are formed. When the oxygen supply is limited to an extreme, only carbon (soot and smoke) and water are produced.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \text{ (plentiful air)}$$

$$CH_4 + 3/2\ O_2 \rightarrow CO + 2H_2O$$

Jet fuel is a mixture of heavier hydrocarbons than those found in gasoline and is far less volatile. Gasoline is a mixture of hydrocarbons containing molecules with five, six, seven, or eight carbon atoms per molecule; jet fuel is composed of eight, nine, and ten carbon atoms per molecule. When equilibrium is reached in the combustion process of jet fuel, it has a burn rate of ten to twelve inches per hour or three-sixteenth's of an inch per minute. This rate is independent of the area of the spill.

Thick, black smoke is produced by the incomplete combustion of the fuel. The perfect gas combustion process is as follows:

$$C_8H_{18} + 12\text{-}1/2\ O_2 \rightarrow 8CO_2 + 9H_2O$$

The above formula, however, which is the formula for complete gas combusion, does not even occur in an automobile engine. It normally occurs only in a laboratory situation. When jet fuel undergoes combustion in the engine or a spill, water vapor is formed first, using most of the available oxygen. This is due to the jet fuel's molecular structure being similar to gasoline. The carbon atoms are screened by all the hydrogen atoms. Once the carbon atoms are exposed, carbon monoxide and dioxide are produced, although the enthalpies of formation (H^{o}_{f}) of carbon dioxide and water vapor dictate the reverse process:

$$CO2 \quad \Delta H^{o}_{f} = -94.05 \text{ k cal/mole}$$

$$H_2O \quad \Delta H^{o}_{f} = -57.80 \text{ k cal/mole}$$

$$CO \quad \Delta H^{o}_{f} = -26.42 \text{ k cal/mole}$$

More heat is liberated in the formation of carbon dioxide than carbon monoxide or water vapor; carbon dioxide is more stable.

Carbon oxidizes very slowly in the atmosphere, but not in combustion. Air is composed of approximately 78 percent inert nitrogen, 20 percent oxygen, and 2 percent other gases. Oxygen is totally or almost totally consumed in the production of water vapor and water vapor replaces oxygen. A large quantity of oxygen is needed for the combustion process of heavy hydrocarbon fuels, as seen in the previous equation of the gasoline combustion process. Air cannot support a complete combustion process. Once combustion begins, oxygen is depleted from the fuel due to the heated water vapor rising constantly off the surface, pulling oxy-gen wi h it in violent motion. Water vapor is also a colorless, odorless gas, as are the other gaseous products of combustion.

The red flames seen at the perimeter and base of the fire are due to carbon oxidation. The oxygen supply is more plentiful at the perimeter than the center of the fire. The red flames, sometimes seen in the thick black smoke, are due to oxygen induction into the smoke in ambient concentrations, with the heat supplied by the flames below. Carbon is oxidized into carbon monoxide and carbon dioxide gases.

Smoke is the dispersion of finely divided solids or liquids in a gaseous medium. The solid particles are suspended in air by molecular attraction, air currents, and heat. These particles fall when oxidized or cooled. Black smoke from a fire consists of carbon atoms. For smoke to occur, the combustion of hydrogen atoms must produce water, leaving the carbon atoms untouched.

Jet fuels are hydrocarbon fuels, which are organic compounds that have a relatively high carbon content. Jet fuels tend to burn with a very sooty flame, even in a plentiful supply of air.

Aromatic hydrocarbons, which are mostly cyclic compounds, burn with more accompanying soot than the aliphatic hydrocarbons. Aliphatic hydrocarbons are usually straight chain molecules that contain five or less carbon atoms per molecule. The flames of burning hydrocarbons are blue with an adequate air supply; reduction of the air supply results in the flames becoming yellow. When the air supply is reduced further, the flames are visible as orange to red color.

For effective fire and smoke simulation of aircraft fires (on a 50 to 1 scale, for example), a heavier hydrocarbon fuel is needed for the combustion. A fuel spill on the ground might be 50 feet in diameter, but the simulation is only one foot. When identical fuels are burned, the one with the smaller diameter burns more cleanly. This is due to more air being exposed to the fuel vapor, so the reaction is pushed toward complete combustion. A heavier hydrocarbon fuel must be used to have the same degree of incomplete combustion.

One of the heavier hydrocarbon fuels at room temperature (65°F) is pentadecane, which has a melting point of 50°F. A tem-perature lower than 50°F will cause the fuel to solidify. Other fuels that were considered are tetradecane (melting point 43°F), and tridecane (melting point 10°F). These hydrocarbon fuels contain 15, 14 and 13 carbon atoms, respectively. For these fuels to undergo complete combustion, at least 20 oxygen molecules or 40 oxygen atoms must be present to completely oxidize one molecule of fuel. This amount of oxygen is more than one and a half times that necessry for the gasoline combustion process. This is an incomplete process in open air. Air cannot supply enough oxygen for combustion to enable these heavy hydrocarbons to produce greater amounts of smoke and red flames for the proper simulation.

Although these fuels were studied and considered, it was determined by experimental results that the simulation of flames on a continuous basis by the burning of hydrocarbons was not a feasible solution to the simulation problem.

SECTION III

STATE-OF-THE-ART REVIEW

Chanute AFB, IL was visited to familiarize project engineers with the driving and fire fighting characteristics of the AS32/P-4 crash rescue vehicle.

A crash truck was taken onto the runways and project engineers operated it in the pumping and driving modes. The engineers became thoroughly familiar with the unique clutching systems of the P-4 so they could simulate the combination gas pedal and clutch arrangement.

The Air Force crash rescue crew demonstrated the operation of the vehicle on a C-130 aircraft, which was there for fire fighting training.

With this background, the project engineers then conducted interviews with commercial concerns to develop a simulator which would meet the needs of the Air Force.

1. COMMERCIAL DRIVER TRAINING SIMULATION

Considerable time was spent investigating the following types of training used commercially:

a. The Ryder Driver Trainer is used for the training of over-the-road truckers and fire apparatus operators. This system utilizes a mock-up of a truck cab: a screen in front of the driver simulates the road ahead; a slide projector flashes the appropriate scene on the screen to the driver. In addition, the two side mirrors (also small projection screens) display the rear view, as would be seen from a truck in its driving mode. The switching of the slides is synchronized to a pre-programmed format and the student must react as the scene changes.

In addition to the visual simulation, there is audio simulation of the diesel engine sounds. There is a physical simulation in the wheel, the gear shift mechanism, the brake, the gas pedal, and the driver's seat. This simplistic simulator has not been received well by the civilian fire service. The major disadvantage is that the instructor must make too many subjective decisions to evaluate the quality of the drivers. The lack of realism was very apparent. As a result of the slide projectors flashing different scenes, there was no smooth transition from one scene to another. The scenario is pre-determined and the driver is forced to react judgmentally to the route presented to him. The system does not have the means to vary the route if the situation is warranted. There was a very limited choice of interactive capabilities. There was no use of dissolve techniques and the slide changing flicker was objectionable, as was the noise of the slide changes.

The techniques for the engine sound and the mechanical components for the brake, gas pedal, steering mechanism, and the gear shift were desirable aspects of the simulator. Commercial driving simulators are not designed for fire fighting. They are neither realistic nor can they be modified easily for fire fighting simulation.

2. EXISTING SIMULATION HARDWARE AND SOFTWEAR

Investigation was made of both analog and digital servo systems for the possible control of TV camera equipment.

a. Discussions with Flight Safety, Inc., of Marine Air Terminal in New York City, were held for a comprehensive review of their extensive simulation hardware. They are a commerical simulation training corporation and have both marine and aircraft simulators.

b. Discussions were held with the McDonald Douglas Corporation. They supplied complete brochures and technical information on their VITAL (Visual Simulation System). This system has some beneficial aspects; it is completely digital, as there are no model boards or servos. Extensive simulation has been done by McDonald Douglas; unfortunately, the simulation has been exclusively in the area of flight training using computer generated imagery. The visual presentation is limited to items such as a MIG 21 and the underside of a KC-135 tanker in flight; these show the fuel drogue, military tanks, etc.

This system has one major disadvantage. In order to be developed in compliance with the requirements for driving and fire fighting scenarios, an extremely large software program is necessary. The estimated price range for the unit was approximately 12 to 20 million dollars, which included the programming of fires, smoke, and aircraft. The basic video presented is a black/white projector type TV which can simulate night, twilight, fog, and hazardous conditions in limited areas, such as aircraft landing and take off, and combat conditions. This is a severe limitation for fire fighters, as the color difference between smoke and flame are very important visual clues.

c. Redifom Simulation, Inc., is a British/American corporation that has the capabilities for color simulation. This system was designed for aircraft, as was the McDonald Douglas system. Their new simulator series has been specifically designed for commerical airlines.

d. Existing simulation hardware and software are used for aircraft training devices. Their basic costs, as well as the cost to modifying them for fire training, makes them prohibitive.

3. VIDEO SIMULATION

Investigations were made into the use of video tape recording systems for the simulator developed by the following companies:

a. Electronic Systems Products - manufacturers of high powered colored projectors.

b. Ampex Corporation - manufacturers of video tape recorders, portable cameras, production editors, and video switching systems.

c. Luxor Corporation - media storage and retrievable systems.

d. Opti-Gone - optical illusion equipment.

e. Tiffen Corporation - dissolve, record, and playback controls of high speed slide projectors.

f. Mast Development Corporation - microcomputer dissolve system for easy high speed slide projection without the high flicker.

g. Pacer Systems Advanced Simulation Techniques - aircraft simulation.

h. Simulation Systems, Inc. - topographical map and mosaic construction.

i. Digital Equipment Corporation - computerized control. Their SP II system is one of the most realistic color presentations seen in Computer Generated Imagery (CGI). However, the limitations are in the flexibility of the system and the cost. The unit cost is in the same range as the McDonald Douglas unit, well above 10 million dollars. Also, after the program would have been written, the cost of changes would have been prohibitive. For example, if the A-7 were deleted from the Air Force inventory, and a new generation of fighters included, the cost of a new scenario could run in the many hundreds of thousands of dollars.

j. Certain video simulation techniques and components, such as the wide angle video camera, were deemed to be technically capable and cost effective. These components were further investigated for incorporation into the concept design of a simulator.

4. SPECIAL EFFECTS

Investigations were made of motion picture special effects.

a. Walt Disney Studios' Visual and Special Effects Department provided information on their burning techniques and smoke generators. Disney studios burn cars and houses when they need burning cars or burning houses; no simulation is used. They produce heavy, dark smoke by burning piled rubber tires. These methods were not considered useful for this Air Force study.

b. Subsidiaries Magic Cam, Howard Anderson Company, and Film Effects of Hollywood produce and execute special effects for

Paramount Studios. They operate a TV mode, one of the most successful of which has been Star Trek. Magic Cam is now supplying some of the servo equipment for the Boeing 757 simulator. The servo mechanics are a 0-30v DC analog control device that can be controlled directly through a microcomputer the LSI-11. The programming language used is FORTH, which could be a problem because it is not a standard language. They have servos available up to 500 watts.

c. Discussions were held with Lucas Studios. They are the company that make Star Wars Films. They use a very expensive process for modeling and also operate in the film mode.

d. Special effects manufacturers have certain devices, such as the microcomputer control servos, which are an excellent method of creating the necessary motion for a fire fighter simulator. Their smoke and fire simulations proved to be nonapplicable.

5. THEATRICAL LIGHTING TECHNIQUE

Initially the use of colored gels to light C02 gas, which would flow from nozzles adjacent to the model, was investigated. This technique at first showed little promise, but did provide the most cost efficent, clean solution to simulate smoke and flames. After considerable effort, the technique was refined and improved. This refined technique provided very realistic simulated smoke and flame.

6. FIRE AND SMOKE

A chemical engineer worked on the concept of generating an actual fire around a model. There are three possibilities by which the fuel may be placed on the simulator. One is manually placing the fuel on the ground or aircraft by the operator and igniting the fuel. The second possibility is feeding the fuel to the ground by injectors from beneath and igniting by a spark generator. The injections would be controlled by a computer using a grid system to control flow. The third option may be, if the flame is more important then the smoke, burning the fuel in a separate area or container and passing the smoke through a feeder to the nozzles. This smoke should not be contained for long periods of time or travel long distances, because the smoke will cool and carbon particles will fall out.

The first and third concepts were not constructed. The second concept, a model, was constructed and studied. Any smoke resulting from the model was forced by a fan (on top of the model) through an air filter, to trap the carbon soot. The filter needed to be changed periodically as the unit was used. The vent was comprised of the filter and fan, in that order, and the remaining "smoke" was vented to the outside atmosphere. Below the model's cover and under the vent for the smoke, there was a carbon dioxide extinguisher system, which was activated by the operator or a heat sensitive device in case of emergency. The principal behind a carbon dioxide extinguisher is that the temperature is -100°F when the gas is expanding. This causes oxygen depletion, also the fuel cools and freezes, which prevents any damage to the model board. A water sprinkler system was provided to clean carbon soot from the model aircraft and the model board in preparation for the next user.

Each side of the model board chamber had a slide bar to regulate the air supply and wind direction. Wind effect could be enhanced by tilting the ground level relative to the earth. The effect of gravity will cause the smoke to rise or fall as a function of the relative weight of the smoke particles. If the smoke is heavier than air, it will fall towards the floor and this, in effect, will appear as smoke being blown horizontally by the wind.

Performing some tests on the hydrocarbon fuels previously mentioned and on other different types of fuels was considered. The heavier the hydrocarbon fuel, the greater the amount of heat is needed for the combustion process to start. Experimentation was also considered on mixtures of light and heavy hydrocarbon fuels so that the lighter fuel would burn initially and the resulting heat would facilitate the combustion of the heavier fuel. A combination of these fuels would possibly have the proper simulation properties that are needed. However, considering all the problems that occur when using the actual scaled down fire for the simulation, it was decided not to spend the time or money to carry out these experiments.

The use of a scaled-down fire system has three problems. Safety is the number one problem. Anytime hydrocarbon fuels are ignited in a closed area, there is a danger of a system malfunction and an explosion. It would also be possible for the hydrocarbon fuel to burn pieces of the model board and/or camera system, and this would be prohibitively expensive.

The second problem is the duplication of the Reynolds number. This problem occures due to the fact that small fires projected on a large television screen tend to appear as a large cigarette lighter.

The third and serious problem is quadrangular. When working in the video area - flame, light, aperature opening, and depth of fire are all interactive. This presents a serious problem. A great deal of experimentation was performed and it seemed impractical to get the aperature opening closed enough to effect a practical video system; however, this closing of the aperature requires additional lighting to the point that the flame is washed out by the extra lighting.

The use of scaled down actual fire and smoke for fire fighting simulation does not seem to be practically possible.

7. CHEMICALLY GENERATED SMOKE

The visual effects of using CO2 and other chemicals, namely titanium tetrachloride (Ti CL4), were investigated. Titanium tetrachloride, when mixed with water, results in a hydrolysis reaction to form hydrogen chloride. Hydrogen chloride is a component of hydroflouric acid. The hydroflouric acid, when formed, would destroy the optical and servo equipment in a very short order. This reagent was discarded and experimentation began with carbon dioxide (CO2) smoke.

The rich, white smoke produced from the reaction of dry ice and water was investigated. The major problem was that of color, as dark, black smoke was not produced using only dry ice. This problem led to investigation of a video switcher. The use of chroma and level keying to produce desired effects was promising. The less costly level keying could be used with a video switcher to blank out the white C02 smoke billowing from a model and super-impose a continuous video tape of an actual aviation fuel fire. The control of the gas cloud was accomplished by limiting the CO2 gas flow. The overall effect was the increase in volume of dark, black smoke. This technique requires that only flame and foam be generated, and yields extremely realistic "real" time interactive simulation programs.

The final device tested was a non-polluting aerosol catalytic generator, which produced a mist that could be dyed. This technique is presently under development by the NASA Jet Propulsion Laboratory. The design is not finalized and the results, although promising, cannot be considered because it is far from being a final product.

Due to the health and safety hazards, Ti C04 was deleated. However, C02 appears to be the most promising hazard free technique for simulating smoke.

8. FEASIBILITY AND TECHNICAL RISK ANALYSES

Having investigated all the various state-of-the-art techniques of fire fighting and driving simulation systems, it was concluded that it was well within the state of the art to design and build a comprehensive training device to meet all Air Force crash truck training requirements. The technical risks involved are minimal and will not be difficult to overcome.

SECTION IV

SIMULATOR DESIGN CONCEPT

After a thorough analysis of all possible simulation techniques, model board simulation was determined to be the most cost-effective while maintaining the realism necessary for fire fighter training. A concept design is completed, utilizing state-of-the-art video systems, carbon dioxide smoke, theatrical lighting fire, as well as model boards.

The crash rescue vehicle simulation concept design is divided into four independent subsystems:

a. Cab/Projector Gantry/Screen

b. Model/Camera/Gantry/Lighting

c. Fire/Smoke/Foam

d. Computer Control/Instructor Interface

1. CAB/PROJECTOR GANTRY

This system will be composed of a full-scale mock-up of an AS32/P-4 crash rescue vehicle and associated optical projection equipment required to fulfill the 180° field of view, "real time" simulation for both driving and fire fighting training.

The screen system will be comprised of six spherical sections, 30° arc each. These sections are designed for ease of assembly and disassembly. This feature provides transportability of the system.

The projection gantry will be made of structural aluminum tubing to provide required strength and minimize weight. The projectors will be commercial, high-output types. The selection of the Aqua Star projector over the GE light valve significantly reduces cost without sacrificing performance or reliability.

The cab will be an aluminum mock-up of the AS32/P-4 crash rescue vehicle. The interior duplicates the instruments and controls of the actual vehicle.

Studies of large vehicle motion have determined that the most important aspects from the driver's viewpoint are the "G" forces as well as the visual and sound effects. ("G" force is the centrifugal force felt by a driver as he is making sharp turns or accelerating or decelerating rapidly.) The driver perceives the tilt of the windshield as he is making a sharp turn. This will be simulated by tilting the cab of the truck as the scenery stays in a constant plane.

The cab of the truck will be mounted on two I-beam gimbals and simulate both the driving forces that are felt and seen by the driver. Additionally, chair motion will simulate acceleration, deceleration, and turning "g" forces. The seat mechanism will provide the inertial force feel associated with the driving simulation.

The steering assembly will also provide interface to the contour sensors. This interface will produce sensory perception in the seat and hands of the student. The only other clue provided for student response will be the roll and dive actuator on the balanced gimble assembly which cradles the cab. These actuators will be interfaced with the computer subsystem and provide dive and roll associated with turning, braking, and acceleration.

The cab assembly will also contain infrared heater assemblies which will be directly interfaced to sensors on the camera probe. These sensors will detect the presence of the red theatrical lighting which simulates the fire; the greater the red light intensity, the greater the heat the student is subjected to. The engine sound will be duplicated as a function of road conditions and fuel rack postion. The heater assembly and the noise produced by the computer-controlled sound system will duplicate the desirable environmental stress associated with actual fire fighting.

2. MODEL/CAMERA/GANTRY/LIGHTING

The model portion of this subsystem will be divided into two sections of different scales. The fire fighting section scale will be 100:1 and the driving section scale is 500:1. These scales yield realism for the fire fighting smoke and flame at 100:1 and provides one square mile of scaled runway and Air Force base on the driving portion at 500:1.

The camera system will utilize a six-sided prism to divide and separate the image and project each 30° section onto a corresponding Vidacon television camera. This camera and probe system are mounted on a gantry, which will provide servo-motions in the X,Y and Z directions.

The gantry design will be the optimum way to transport the video system. There will be a dividing wall between the fire fighting operation and driver operations. This wall will be movable to enable the instructor to proceed immediately from a driver training class to a crash operator's class. It has been determined that the overhead gantry is a better choice than a vertical gantry, to simplify the control of smoke and simulated wind directions.

The correct wind direction is determined by a computer calculation. The lighting of the model board will be accomplished by a structural support system, which holds banks of flourescent bulb assemblies.

3. FIRE/SMOKE/FOAM

This system will be comprised of a scale model crash scene where C02 and lighting, under computer control, produce scaled, realistic smoke and flame. The crash scene also will have sensors which will detect the intensity of the ambiant light and will be calibrated to respond as simulated foam is placed upon them. These foam sensors will be are the control points to allow realistic flame response to agent application. The flame/smoke generator and the foam application sensors will be mounted beneath a perforated metal screen. The screen's thickness, perforation diameter, and spacing will be selected to be invisible to the student, but adequate enough to allow smoke and lighting to come from underneath. The student will view an apparent flat, solid runway.

The smoke generation system used to simulate large billowing clouds of smoke around the model aircraft will be a C02 system which is nontoxic and commercially available. The fire simulation portion will use high intensity orange spot lights of a theatrical nature, displayed through various openings and flashed on to the base of the smoke, to give a tremendously realistic demonstration of fire conditions around the aircraft.

The simulated foam system will be comprised of several components. The foam will be made up of microscopic glass spheres called micro-ballons; these are stored in a remote chamber with an external filler port. The bottom of the chamber will have an induction nozzle with compressed air carrying the microballoons to a storage chamber mounted on the side of the camera probe. The compressed air and microballoon mixture will be separated in a Vortex chamber, with the microballons dropping out and down. The air and excess microballoons return to the storage chamber where a Vortex separator is vented through a filter to the atmosphere. The storage chamber at the camera probe will have an induction nozzle powered by compressed air. The nozzle flow will be controlled by the student; i.e., valve setting in the cab varies the air flow which in turn varies the foam flows. This nozzle will connected via tubing to a miniature remote-controlled direction assembly beneath the prism of the camera probe. The foam, when discharged onto the model board, will be sensed by the intensity changes which occur due to microballoon coverage. When correct coverage is attained, the smoke valves and lamps for that area are switched off.

Clean up will be accomplished by a vacuum assembly which has a molded fiberglass hood that covers the crash site. Compressed air will be used to agitate the microballons out of the smoke and flame simulation screen and are swept away by the vacuum pump. The dischage of the vacuum will be routed back to the storage area, where a Vortex chamber separates the microballoons into the storage container. Excess air will be discharged through a filter to the atmosphere.

4. COMPUTER CONTROL/INSTRUCTOR INTERFACE

The computer subsystem will utilize 16 bit duplex registers for digital input and output, A/D interface for analog input, and produces analog output via D/A converter interface. This subsystem will gather the input data from the cab and model board with respect to direction, speed, and terrain. This subsystem then outputs x-direction, y-direction, and z-azimuth rotation to the servomotor assemblies on the camera gantry assembly.

Additional data will be obtained from the pin diode sensors mounted on the camera probe assembly. This assembly will also interpret terrain features which will be analyzed to give corresponding seat, steering wheel, and cab vibration, tilt, and roll.

The instructor interface will consist of: (1) a computer terminal, (2) gages for air pressure, voltage and current meters for fault isolation, and (3) interface for controlling the instruments in the cab to simulate failure to oil pressure, air pressure, etc. In addition, the fire/smoke field shape select switches will be part of the instructor interface. These switches will allow the instructor to change the size and shape of the fire and create engine fires in the aircraft model.

SECTION V

CONCLUSIONS

Having investigated all state-of-the-art simulation techniques, the following can be concluded:

1. An economical and practical crash rescue simulator is conceivable. A conceptual simulator design in the form of a AS32/P-4 crash rescue vehicle was formulated and developed.

2. The construction for the Air Force crash rescue vehicle simulator is well within the state of the art for today's technology with minimum technical risk.

SECTION VI

RECOMMENDATION

The following recommendation is given:

1. A working model fire fighter vehicle training simulator be constructed, tested and evaluated for Air Force operational use.

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